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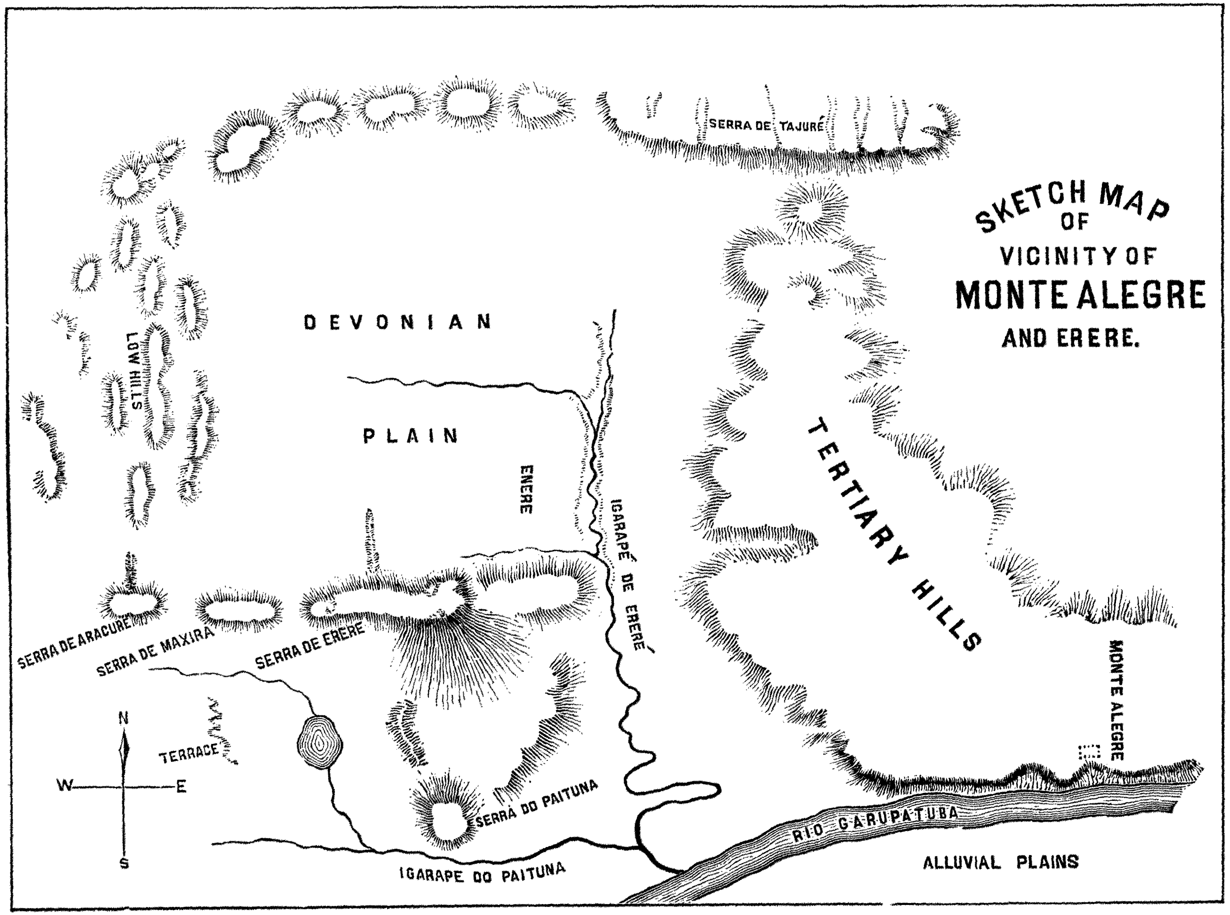

SKETCH MAP OF VICINITY OF MONTE ALEGRE AND ERERE.

VII.

RECENT EXPLORATIONS IN THE VALLEY OF THE AMAZONAS, WITH MAP.

BY CHAS. FRED. HARTT, M. A.,
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READ MAY 16TH, 1871.

ON THE PHYSICAL HISTORY OF THE AMAZONIAN VALLEY.

The history of the Amazonian Valley anterior to the Devonian is involved in much obscurity. It first appeared as a wide strait between two islands or groups of islands, one now forming the base and nucleus of the Brazilian plateau, the other, on the north, the plateau of Guiana. These islands made their appearance at or shortly after the beginning of the Silurian age. At this time the Andes did not exist.

The rocks of the lower rapids of the Tocantins, as far at least as the Cachoeira da Guariba, consist, in the main, of a thick series of more or less altered shales, sandstones, impure limestones, etc., highly inclined to the northward, and traversed here and there by trap dikes. These rocks have afforded me no fossils, so that I am unable to determine their exact age. They are probably, however, Silurian.

I have never visited the rapids of the Xingú; but Prince Adalbert, of Prussia, who in 1842 ascended that river to some distance above the first cascades, in company with the Counts Oriolla and Bismarck, reports the prevailing rocks of the lower rapids to be granite and gneiss, and the same observer speaks of the occurrence of clay-slate just below the last cachoeira.*

* In Brazil this term is applied to rapids as well as falls or cascades.

At the lower rapids of the Tapajos, as far at least as the Apuím, I found red sandstones, resembling closely our Potsdam Sandstone of New York, broken through, disturbed, and altered by immense dikes and masses of a coarse red porphyry, sometimes with very large crystals of feldspar. This sandstone is certainly pre-Carboniferous, as immediately below the last fall we find, undisturbed and unaltered, Carboniferous strata, which I shall presently describe.

In the vicinity of Monte Alegre and of the Serra do Ereré, undoubted Lower Devonian rocks, with an abundance of beautifully preserved and characteristic fossils, occur.

This region is so very interesting, on many accounts, that I will describe it somewhat in detail, and with the aid of a sketch map.

The mountains of Ereré form a group lying some eight miles west of the Villa do Monte Alegre, and about fifteen or twenty miles north of the main river Amazonas. The Serra of Ereré proper is a narrow, irregular ridge, four or five miles long, trending from east-north-east to west-south-west. On all sides it is very abrupt. On the north a broken line of craggy precipices runs along the edge of the Serra, below which the slope is steep and talus-like. This side of the Serra is extremely picturesque. The line of precipices is formed by beds of coarse sandstone, ordinarily very hard and of a white or reddish tint, which strata conform in strike to the trend of the mountain and dip toward the southward at an angle varying from five to twenty degrees. The latter angle is the highest I have observed. The inclination is so great that in the precipices of the eastern end of the Serra it is observable from a long distance. On the southern side the mountain is very irregular, steep and often precipitous; but the top may be reached in one place by a long, sandy, inclined campo. The summit is so broken, rocky and irregular, that it is a difficult task to traverse the ridge from end to end.

From the description I have given of the Serra do Ereré it will be seen that it is composed of disturbed strata, and moreover that in this respect, as well as in its topographical features, it bears no resemblance to the flat-topped hills farther east, to which system it has, however, been referred.

To the south of Ereré is a much lower, irregular patch of the same strata, forming a sort of plateau called the Serra do Paitúna, beneath which, according to an Indian legend, an enchanted being of the same name has hidden himself. There the rocks, according to my young companion, Mr. Staunton, lie very flat. Both in the Serra and in Ereré, the strata, being often of unequal hardness and well jointed, have been worn into strange drongs, pillars and tables. A curious and very conspicuous mushroom-like table stands on the top of Paitúna, on the southern side, and bears the name Induá (mortar, *Tupí*), or in Portuguese, Pilao, from its resemblance to one of the huge wooden mortars so commonly used in Brazil.

In some places the rock has been excavated, forming caves, and, a large bat-inhabited grotto, situated most picturesquely on the side of Ereré, among the crags, is called by the Indians, Tupaóca; literally, "God's House," or the church.

Westward of Ereré, and separated from it by a deep notch, is a short ridge of the same general character and geological structure, called the Serra do Maxirá; and beyond this, a short distance to the westward, is a similar hill that appears conical when seen from the east. It bears the name of Aracurí. I have not visited it. The only fossils so far found in the Ereré sandstones are fragments of fossil wood, which, when examined, may perhaps aid in the determination of the age of these strata. These remains were found by Mr. J. B. Steere, who accompanied me on my last visit to the mountain, in 1872.

From the northern side of Ereré, a very narrow, sharp, wooded ridge starts abruptly from the Serra and extends northward for a mile, more or less, with an even height of 150 feet or more. It is then cut through by a gap, on the other side of which it continues in the same direction for some distance. In the gap, the lower part of the ridge, to a considerable height, is seen to be composed of a heavy mass of diorite, but whether it forms a bed or a dyke, I had no means of determining. A road passes through the gap, and is much gullied out by rains, exposing a great abundance of boulders of decomposition, which might readily be mistaken by a superficial observer for erratics.

The top of the ridge appears to be composed of a rather compact, not well laminated clay rock, mottled red and white, and without fossils, the beds dipping at a moderate angle to the west. A similar ridge appears to be attached to the hill Maxirá, but an attempt to examine it proved a failure, as I lost myself in the thick woods.

From Maxirá and Aracurí there extends northward a narrow zone of low, wooded ridges, which gradually bends round and culminates at a distance of fifteen to twenty miles to the north-north-east of Ereré, in the high and beautiful ridge of Tajurí.* Of this zone of high lands between Maxirá and Tajurí I cannot give an intelligent account, owing to the want of sufficient exposures, and of the difficulty of recording accurately observations made in a tangled forest, and in the beds of the extremely tortuous igarapés † (brooks) which one is obliged to follow.

This hilly region appears in the main to be composed of the same mottled clay rock above described ; but I have found also shales, some of which are finely laminated, and of a dead black color. Numerous dykes of trap intersect these rocks and are exposed in the beds of the igarapés. Here and there are heavy superficial deposits of hæmatite ore, more or less impure.

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* Often written Tajury. The Tupí name appears to have been Tauáyurí.

† Literally, canoe path, a term applied on the Amazonas to all small streams, whether navigable or not. *Ygára* is canoe, and *pé* path. Ygára appears to be derived from *yg*, water, and *yára*, lord, master; whence *ygarapé* (*igarapé* Portuguese form) would mean, *path of the lord of the water.*

Attempts were made by Mr. Herbert H. Smith and myself to reach a high hill north of Ereré, but the thick and tangled undergrowth, full of Yuruparí-pindá (Devil's fish-hooks) and other thorny plants that cover its vicinity, prevented our reaching it. I found a sort of plateau lying in front of the mountain, in part at least composed of diorite, like that of the ridge near Ereré.

Tajurí is a fine, sharp crested monoclinal ridge, trending approximately south-east and north-west. The upper part is composed of a series of shales, sandstones and clayey rocks, barren of fossils and very different from anything I have seen elsewhere. They dip to the north-east at an angle of about twelve degrees. The lower rocks of the series I did not see exposed.

Toward the south-west the Serra is very steep, almost precipitous, a line of low bluffs running along near the top indicating the position of a bed of sandstone. To the north-east the mountain slopes off at an angle of ten to fifteen degrees, in a series of beautiful grassy campos, interspersed here and there with trees. This side of the Serra is scored by deep ravines formed by pluvial torrents. In many cases these gorges have extended up to and even through the crest of the Serra, causing it to present a notched outline.

At the base of the mountain, at the eastern end of the Serra, are beds of a compact bluish limestone that looks as though it ought to contain fossils, but none were found by myself or party. The locality, Jacaré by name, merits further study.

From near Tajurí to Monte Alegre extends a series of broad, swelling ridges, the remnants of the formation of table-topped hills, which I will describe more fully further on. These heights, together with the Serra of Ereré, and the zone of hills extending thence to Tajurí, form, topographically speaking, a rim to a great plain, that extends up to the base of the hills, on all sides.

Thus far, in our examination of the Ereré-Monte Alegre district, we have found no evidence bearing on the geological age of the strata forming the hills. Fortunately the rocks of the plain afford some light. The last are not drift, as has been claimed, but, as is shown by the abundant and excellently preserved fossils, Lower Devonian.

In 1870, after exploring the Lower Tapajos, I determined to spend a month in the neighborhood of Ereré; but being obliged, first, to go to Pará, I left Messrs. Comstock, Smith and Staunton at Monte Alegre, to await my return. These gentlemen made an excursion to Ereré, and, in the shales described by Prof. Agassiz, they found an abundance of a beautiful little *Discina*. The first day after our arrival at Ereré, I ascended the mountain, sending Mr. Smith out on the plain to reconnoiter, and on my return I found he had brought in several species of *Spirifera*, *Streptorhynchus* and other fossils. The lowest beds of the series composing the plain are composed of a well bedded, extremely hard, almost black, cherty rock, sometimes breaking with a conchoidal fracture; though it is often shaly, especially when decomposed. It has afforded, as yet, no fossils. Above this is a series of shales, white, black, green, or mottled in color, and more or less well stratified. In the lower part of this series, there are thin, alternating layers of white and black or ash-colored shales, affording the *Discina* above mentioned, a *Lingula* or two, and fragments of plants. In the upper part, these shales contain *Vitulina*, *Spirifer* and other fossils, which are found in great abundance in a coarse white or reddish (when decomposed) sandstone which overlies the shales, but is nowhere well exposed, usually occurring as a surface rock, much cracked up, and in loose, angular fragments. Besides *Streptorhynchus*, *Spirifer* and *Vitulina*, this sandstone contains a *Lingula*, a few Gasteropods, *Tentaculites* and a beautiful *Dalmanites*, the latter with the margin of the pygidium, furnished with long, backward-projecting points. These fossils have a strong Lower Devonian facies. Prof. James Hall, to whom I submitted a small collection for examination, is of the opinion that these fossils indicate a horizon near the Upper-Helderberg of New York.*

The whole thickness of these rocks visible is not more than seventy-five to one hundred feet. The plain is a little higher on the northern than on the southern side.

Though these strata are broken through by a perfect network of dykes, which here and there stand above the surface of the plain like ruined walls, they lie quite undisturbed. They appear to have been deposited in a basin, limited by the Serra of Ereré and the zone of hills on the west and north. The highlands of Monte Alegre are formed of clays and sands that overlie the Devonian strata.

As the strata composing Ereré and Tajurí are inclined, while the Devonian rocks of the plain lie quite horizontal, appearing to abut against the bases of both mountains, it would seem natural to conclude that the strata of these hills are older than those of the plain. If they are newer, the Devonian strata must suddenly dip under both moun-

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*In the summer of 1871, I revisited Ereré in company with Mr. O. A. Derby, my faithful and able assistant, and Mr. Steere. Mr. Derby and I made a very large collection of the above fossils, embracing many species not obtained by Mr. Smith and myself in '70. This collection has been arranged by my friend and student, Mr. Richard Rathbun, curator of geology in the Buffalo Academy of Science; and with his aid I am preparing descriptions and figures of the species. The Ereré fauna comprises about twenty-five species of *Brachiopoda*, of the following genera: *Spirifera*, *Vitulina*, *Tropidoleptus*, *Rhynchonella* (*Stenocisma Hall*) *Rhynchospira*, *Cryptonella* (?), *Streptorhynchus*, *Chonetes*, *Orthis* (?), *Lingula*, *Discina*, etc. Of *Lamellibranchs* there are about twelve species belonging to the genera *Nuculites*, *Palæoneilo*, *Cypricardinia* (?). Besides the above are several species of *Gasteropoda*, representing the genera *Pleurotomaria*, *Bellerophon*, *Platyceras*, *Tentaculites*, together with several Trilobites, one of which is a *Dalmanites*. In all, the number of species amounts to about fifty.

tains, and of this I see no evidence. At all events, neither Tajurí nor Ereré belong to the system of the Table-topped hills, and neither has the slightest claim to be considered to be of glacial origin.

The Ereré Devonian plain is partially wooded, principally along the water-courses or igarapés. The forest is far from luxuriant, and has a dense undergrowth of curuá palms (*Attalea*). The soil of the campos varies very much. Where alluvial, it is, for the most part, wooded; but usually it is very thin, and often so extremely stony that the surface appears macadamized and is quite sterile. The soil is for the greater part covered with a layer of small iron-stone nodules of about the size of beans, and with a glazed exterior. On the dry campos, which are usually covered with grass and scattered trees, immense candelabra-like cactusês (*cereus*) are not uncommon, and forceably recall the campos region of southern Brazil. The forest in the perennially wet and alluvial grounds, or along the base of the mountain, is sometimes very dense and luxuriant, and abounds in murumurú (*Astrocaryum Murumurú* Mart), urucurí (*Attalea excelsa* Mart), mucajá (*Acrocomia*), and other palms. There are in the vicinity of Ereré some magnificent groves of urucurís. Prof. Agassiz has already referred to the forests of miritî palms (*Mauritia flexuosa*) which occupy marshes overflowed during a part of the year.

The vegetation of the Serras resembles that of the sandy campos, the trees being scattered and small. The cajú or cashew (*Anacardium occidentale*) and the yatá and sacurí palms are very common on the mountains. There is an immense patch of cactuses on the southern side of Maxirá.

The soil on the high, swelling ridges near Monte Alegre is a coarse and loose sand, and supports a campos vegetation. The trees are scattered, low, gnarly-branched and coarse-barked. As on the Serras, the cajú is very abundant, but it does not grow on the Devonian plain.

From the fruit of this tree a delicious wine is manufactured, especially at Santarem. The campo is covered with grass, that grows in wiry, scattered tufts. This is yearly burned over, the campos fires contributing largely, as in central Brazil, to give the peculiar character to the vegetation.

To the southward of the Ereré hills and Monte Alegre we have the great, open, grassy, alluvial plains of the Amazonas, diversified by irregular lakes and immense groves of the mirití, and traversed by *igarapés* and *paraná-meríns*, bordered by strips of forest.

Dr. Silva Coutinho appears to have been the first to have collected the Carboniferous fossils of the vicinity of Itaitúba, on the Lower Tapajos; but he did not identify them as such, nor did he make any systematic examination of the locality. Moreover, I do not know that he has ever published any notice of his discovery. Prof. Agassiz simply says:* "Maj. Coutinho has found Palæozoic deposits, with characteristic brachiopods, in the valley of the Rio Tapajos, at the first cascade; and Carboniferous deposits have been noticed along the Guaporé and the Rio Mamoré." The only other notice of Dr. Coutinho's work is made by Mr. Chandless, who says:† "It may be well to add that Dr. Coutinho found (as Prof. Agassiz told me) Silurian fossils at one of the lower rapids of the Tapajos, in about latitude 4° 32′ south." The fossils found by Dr. Coutinho are Lower Carboniferous, and the locality was not at the first cascade, but in the vicinity of Itaitúba.

In the summer of 1870 I made a detailed examination of the Carboniferous rocks of the Tapajos, from the rapids to Itaitúba, and, with the help of my young assistants, made a handsome collection of fossils, especially from Itaitúba and the Igarapé do Bom Jardim. In 1871 I spent a month at Itaituba, during which, with the aid of Mr. Orville A. Derby, I made a more careful study of these rocks, and collected several thousand specimens of the fossils, including many species not found in my previous collection. Illness preventing my going in person, Mr. Derby examined the Carboniferous strata between Itaitúba and Aveiros. The Carboniferous rocks begin just below the entrance to the lowest rapids. Here the beds consist of sandstones, which are horizontal and without fossils. At Tapéra Alagada I found chert nodules with a few *Producti*, etc. At Barreirinha, on the left bank and several miles farther down the river, there are exposed in a bluff, shales mostly soft and of a blue color, with imbedded septaria composed of a very curious mottled rock, and containing *Ichthyodorulites* and other fossils, among which may be mentioned an *Orthoceras*. In the shales I found a single specimen of a *Lepidodendron* or *Hemingites*. Shales with septaria appear, below Barreirinha, in a long line of bluffs on the right bank, and, also, on the opposite side of the river, below the Igarapé do Uatapucurá, where I found them full of spore cases of *Lepidodendron* or *Hemingites*.

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* A Journey in Brazil, p. 408.

† Notes on the Rivers Maué-assú, Abacaxís, and Canumá (Amazon), Jour. Roy. Geogr. Soc. (London, 1870), p. 4

Just above Itaitúba compact limestones appear in low bluffs on the left bank, at the Paredao. This limestone is full of fossils ; but a better locality for collecting them is on the Igarapé do Bom Jardim, a little farther down on the same side of the river. On the banks of this little stream the limestone frequently forms shelf-like masses, beneath which are grottos. The shells, corals, etc., in the limestone, are, for the most part, silicified ; and the water of the Igarapé, at flood time, has eaten away the lime rock, washing out the fossils, either leaving them projecting from the sides and roof of the grottos, or attached by a mere thread of stone, and ready to fall into the hand. These fossils are particularly valuable because they are not only well preserved, but they show the interiors.

The number of species is very large. Among them may be mentioned a *Productus* resembling *P. Cora*, and another resembling *P. semireticulatus*; a beautiful little *Strophalosia* preserving its spines; together with species of *Rhynchonella*, *Orthis*, *Spirifer*, *Athyris* and other brachiopods; a large number of lamellibranchs, gasteropods, polyzoans, and a few crinoids and polyps. Some of the beds of limestone are full of thick, tortuous, root-like casts. Flint-like nodules also occur in the limestone.

At Itaitúba a series of rocks, very badly exposed on the beach that borders the village, affords an abundance of similar fossils, and some boulder-like masses of sandstone are full of large lamellibranch shells, together with a few cephalopods, gasteropods and a pretty trilobite (*Phillipsia*).*

The limestones occur at several localities a few miles below Itaitúba; and they have at one of these localities, as well as at Bom Jardim, been used to make lime. They also occur on the Rio Cuparí.

Below Aveiros the Carboniferous strata disappear below the level of the river, and they doubtless underlie a very large part of the basin. I am strengthened in this conclusion by the fact that Mr. Derby obtained from Senhor Gabriel of Obydos, specimens of the flinty rock like that of Itaitúba, and containing characteristic Carboniferous fossils, which the latter gentleman collected on the Rio Trombetas, on the northern side of the valley.

Mr. Chandless, in the paper above referred to, describes finding fossil shells, among which were *Spirifer* and *Productus*, in a limestone grotto on the Rio Paranary, a tributary of the Maué-assú lying west of Itaitúba. His description of "what look like fossil roots *in sitû*," leaves no doubt that these rocks are the continuation of the Itaitúba series. They also occur, according to the same observer, on the Rio Amâna, another affluent of the Maué-assú, lying between the Paranary and the Tapajos. Prof. Agassiz, as above quoted, states that Carboniferous rocks exist on the Guaporé and Mamoré tributaries of the Madeira. All these facts go to show that the Carboniferous has a wide extension in the Amazonian basin.

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* With the aid of Mr. Derby I am preparing descriptions and figures of these fossils, which will be published as soon as possible. Twenty-eight species of brachiopods have been made out. These belong to the genera *Streptorhynchus*, *Spirifer*, *Athyris*, *Productus*, *Strophalosia*, *Chonetes*, *Spiriferina*, *Rhynchonella*, *Orthis*, etc.; and the species are remarkable for their close resemblance to European forms.

No Mesozoic deposits are known to exist in the Amazonian valley east of the Aquiry, an affluent of the Purús, on which Mr. Chandless has discovered Cretaceous beds with fossils. These are, so far as I know, the only Cretaceous beds known to exist on the Amazonas. The statement that "around the rim of the basin are the outcroppings of a Cretaceous deposit," is not warranted by facts. The Amazonas has a better claim to be considered a Carboniferous than a Cretaceous basin. It must be borne in mind that it was not until after the Cretaceous that the Andes-Rocky Mountain chain reached its present elevation, and that the plateaux of Guayana and Brazil were joined to the mainland.

The flat-topped hills so often described by travelers on the Amazonas, and known collectively as the Serras do Parú, consist of several irregular patches and isolated hills, often widely separated, which are situated on the left or northern bank of the river, extending some fifty to sixty miles to the westward of Almeyrim, a little village now quite deserted, and distant about two hundred miles from the mouth of the main river. Von Martius ascended one of the hills in the vicinity of Almeyrim and reported it to be eight hundred feet high. He made no study of the geology of the hills.

Very different conclusions have been come to as to their geological structure, and Prof. Orton tells us that they are composed of "a coarse, porous sandstone, so ferruginous as to resemble bog-iron ore."* But the cliffs, distinctly visible from the river, are chalk white !!

On my journey, in 1870, I had chosen the Serra of Ereré for study, supposing, after Prof. Agassiz, that it was a representative of this class of hills. I had no time left, after visiting Ereré, to examine the Serras do Parú, and I could only depend on certain topographical features, which quite satisfied me that, unlike Ereré, these last Serras were composed of soft material, horizontally stratified, and probably the continuation of the beds forming the Santarem bluffs. That there might, however, be no doubt left, I visited, in the summer of 1871, the Serra of Parauáquara, selecting it because it offered precipices where the geological structure would be displayed.

Starting from a cattle fazenda on the Rio Marapí, an affluent of the Javary, I made the journey to the Serra on foot, spending three days on the trip. Though the Serra appears very near when seen from the river, it is, in reality, very distant, certainly more than ten miles. By the direction we took, it is not less than twenty miles from the fazenda above mentioned ; though, in a straight line, it may be nearer. Strange to say, the Serra and its vicinity were to every one a *terra incognita*, and the people were so superstitious that they were afraid to visit it !

Going eastward, the greater part of the country we traversed was uneven, and, near the Serra, very hilly, the surface being covered with blocks of ferruginous sandstone. It was an alternation, or, more properly speaking, a mixture of campo and wood, grassy patches with few trees, and thick but low, dry-looking woods. A heavy, luxuriant forest, however, is found along water-courses and in swampy places, with here and there a jungle of the magnificent, banana-like pacúa-sororóca (*Phœnacospermum*). The campos and mixed country were extremely difficult to traverse, owing to the height of the grass and bushes, and the abundance of sword-grass (cariá), that tore our clothes and wounded our legs and hands. Von Martius has called attention to the great resemblance borne by this vegetation to that of the *campos agrestes* of Piauhy. The ascent of the Serra was made by a sharp spur on the south-eastern corner; but, owing to the abundance of sword-grass and the difficulty of climbing, it was very tiresome. Bates speaks of this Serra as being destitute of trees. It may appear so because of the distance from the river. It is, indeed, bare on the steeper slopes, but the top is covered by a low wood, so thick as to be extremely difficult to penetrate. The sides of Parauáquára are generally very steep, and, in some places, irregularly terraced, owing to the unequal wearing away of the strata. In some places they are precipitous, and at the south-west angle is an immense gulf like one side of the crater of a volcano, which is extremely grand. The serra is composed of a series of clays, more or less sandy, and of different colors, but usually whitish, together with very soft clayey sandstones, white, yellow, reddish or mottled. The prevailing color of the rocks of the series, however, is white. The distinction between the various strata is well marked out, not only in the cliffs, but, also, by parallel lines running along the sides of the mountain; but the different beds are not well laminated. It is hardly necessary to state that the strata composing the serra are horizontal, and that the top is as level as a floor. The uppermost bed is a red, clayey soil. Under this is a thick bed, full of nodules of ironstone, the nodules being long, closely packed and perpendicularly arranged. At the base of the mountain, springs of delicious water spring out as from the bluffs of Santarem.

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* "The Andes and Amazon," p. 281. The same author—who, by the way, "did" the whole valley of the Amazonas, with the Rio Napo thrown in, in less than six weeks, traveling day and night—tells us, on page 252, that the hills of Almeyrim lie back of *Monte Alegre*, *behind a swamp*, and that they are composed of a *pebbly conglomerate !!* These slight inaccuracies are, perhaps, pardonable when we consider that the author, leaving Santarem at two o'clock in the morning, came up off Parauáquara late in the afternoon, and, passing the Almeyrim hills in the dark, was early the next morning assisting in the taking in of wood in Porto do Moz !!!

Away to the north of Parauáquára are seen other hills of the same kind. Judging from the outlines of these Serras, seen from Tajurí, some appear to be perched on a base of a different formation. Moreover, these northern Serras appear higher than those near the river.

No one can doubt that the Serras of Parú are the remains of a formation that was once continuous over this part of the valley; but I see no reason for supposing that it was continuous to the same height over the the whole valley.

On the opposite side of the Amazonas, and a few miles back from the main river, a line of bluffs four hundred feet high, more or less, extends westward toward the Xingú, and southward along the Tapajos river to the rapids. These bluffs are almost invariably very steep and wooded, so that they afford but few sections. Near Santarem, at Panéma, Irurá and Diamantina, and still better at Alter do Chao, where there are several outlying hills, their structure may be well studied. Here we find the same kind of deposits that occur in Parauáquára, and, notwithstanding the difference in height, I am disposed to consider the strata composing the table-lands back of Santarem, and bordering the Tapajos, as the continuation of the Parauáquára series. The Serras on the north side of the river stand at a higher level, probably because of the greater height of the bottom on which they were deposited, the Santarem beds having been accumulated nearer the center of the basin, where the water was deeper. It may, however, be that the slope is owing to the beds having been elevated more in the north than in the south. If this be the case, the question suggests itself whether the serras of Parú are not outlyers of the great Tertiary sheet of the interior of Guayana, where it forms mountains such as Waetipu and Roraima—the former about five thousand, the latter seven thousand feet high, and with mural precipices two to three thousand feet in height*— and whether both may not be of the same age as the great sandstone sheet that spreads over so great a tract in the interior of Brazil. Parauáquára resembles the chapadas of the basin of the Jequitinhonha, and Von Martius has compared the serras of Parú with the table-topped hills of Piauhy. Neither in Guayana, on the Amazonas, in Piauhy nor in central Brazil, have these beds afforded fossils. In my "Geology and Physical Geography of Brazil," I have claimed that they are most probably Tertiary in age. I see no reason for changing my opinion. I see not the slightest reason for believing that the deposits forming the Serras of Parú are of glacial origin, while it is utterly incomprehensible to me how they could have been formed in fresh water, when we have not the first fact to show that any barrier ever existed across the mouth of the Amazonas behind which water could accumulate.

Before the rise of the Andes the Valley of the Amazonas consisted simply of two gulfs, united by a narrow strait. The Andes were thrown up across the mouth of the western gulf, converting it into a basin, though it probably had an outlet both to the north and south. The whole continent was afterward depressed, so that the waters covered widely the Guayanian and Brazilian plateaux, and the Tertiary beds were deposited there, varying in thickness, coarseness or fineness, according to the conditions under which they were formed.

We should expect that these beds should conform in level with the bottom on which they were laid down, lying higher on the shallower borders of the basin, and dipping in every direction toward its center. When the continent was once more brought above water, the plateaux, leveled by their new acquisition of strata, first rose ;

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* Sawkins, Geological Observations on British Guiana. Quart. Jour. Geol. Soc., London, vol. xxvii, No. 108, p. 432.

but by-and-by the present water-sheds, joining the great plateaux with the Andes, came above water, and the Amazonian Valley became a Mediterranean, communicating eastward with the Atlantic by a narrow strait. The soft Tertiary beds of the province of Pará were rapidly denuded by the action of the sea during the rise of the land. Probably while Guayana existed as an island, the Amazonas felt the influence of the equatorial current, which may have aided in the carrying away of the results of denudation. In the end, the Tertiary beds were completely swept away over an immense tract of country; the Serras of Parú, and the similar mountains to the northward, were left as monuments of its existence. At Monte Alegre, Santarem, and near Alter do Chao, the wide, sandy, rounded ridges appear to be remnants of the Tertiary hills which have been worked over, and in part restratified, until they appear like huge sandbanks. While the Tertiary sheet was being denuded away, the streams from the highlands were cutting for themselves valleys through the same beds, and these, forming estuaries, were widened to a greater extent than it would have been possible for the streams themselves to have done. During this epoch of denudation, deposits were being laid down, not only in the bottom of the interior sea, but also in the gulf, into which it opened to the east. It was in the latter part of this stage of growth of the basin that the clays of the upper Amazonas were deposited, and the Pebas shells lived. This appears to have been near the close of the Tertiary. A heavy bed of lignite underlying the clays near Tabatinga, was discovered quite recently by Dr. Pimentel, of the Commission of Limits, a gentleman to whom I am under many and deep obligations.*

As the rise continued, the interior sea, now shallowed by much sediment, and freshened by the tribute of a thousand streams, was rapidly narrowed in area, and the river Amazonas, properly speaking, which heretofore emptied into the lake at the foot of the Andes, began to extend its channel, following the retreating waters. At last, the strait that communicated with the interior basin was narrowed down between the line of hills extended from Obydos to Almeyrim and the bluffs on the Santarem side, a distance of not less than thirty or forty miles. This was the narrowest point. I may add that the channel of the river is narrowed at present, at Obydos, by the growth of the alluvial flats on the southern side.

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* Since the above was written, I have published a little paper "On the Tertiary Basin of the Maranon," in the Am. Jour. Science and Arts, Vol. IV, July, 1872, in which are given the results of a recent examination of the Pebas beds by my friend, Mr. J. B. Steere.

It has been claimed that the strata forming the Island of Marajó and the main land at Pará are continuous over the whole Amazonian Valley. I must confess that I have been totally unable to connect together the clays and sands of the Amazonas intermediate in age between the Almeyrim beds and the modern alluvia.

Pará is built on a sort of ridge about thirty feet in height. The beds of which it is composed are excellently exposed in numerous pits and excavations, and are as follows:

I. A variable thickness of dark, loamy soil.

II. A bed of a loose, yellowish-brown mixture of clay and sand full of coarse grains, passing downward into a light colored material of the same general character, containing an abundance of nodules of all sizes and shapes, and consisting of the above material cemented by iron oxide. In this bed there is occasionally a streak of white or red clay. The thickness of this bed varies very much; in some places being ten or more feet. Elsewhere this bed appears to pass into a mottled clay.

III. An unknown thickness of sand, very pure, coarse and unmixed with clay, usually white, but sometimes red in color.

Bed No. II has been compared with the drift clays of the vicinity of Rio. To me it appears very different. If, now, we examine the southern side of the island of Marajó at Soure, we shall find a bed similar to No. I of the Pará section, and which, like it, contains nodules formed by the irregular consolidation of the lower part of the bed by iron oxide, the nodules coalescing so as frequently to form masses traversed by irregular perpendicular channels. This mode of solidification of loose materials by iron oxide is very common in Brazil, and is found to take place in the lower part of the coast clays of Espiritu Santo and Bahia. I have observed it also in the Carboniferous rocks of the Tapajos. I have already called attention to it in the clayey stratum below the superficial soil of the Serra of Parauáquára. These nodules may occur in any formation. Underneath the bed at Soure, first described, instead of sand we find tabatinga clay. At the Barreiras, just above Cametá, on the Tocantins, the clays are mottled. I have never succeeded in finding the lower stratum of sand of the Pará section in any other part of the province, and I have seen the river at its lowest stage. I cannot help coming to the conclusion that the deposits under discussion are, more or less, local, and not necessarily of the same age. They are certainly newer than the Almeyrim beds. In great part these so-called Amazonian clays are certainly recent.* Not having studied the similar deposits of the Upper Amazonas, I am unable to compare them with those of the lower river.

Whatever may be the age and relationship of the beds of Pará and Marajó, there can be no doubt that the island of Marajó came above water just as the Amazonas was passing out of the estuary condition. The lands bordering the channels by which the Amazonas now communicates with the Pará river, are very recent; and there can be no doubt that, when the island of Marajó rose from the sea, the Amazonas communicated with the Pará by a wide channel.

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* See my paper cited in note on p. 247.

It has been said that there are no terraces in the Amazonian Valley. Just south of the Serra do Maxirá there is a terrace some twenty feet high above the general level of the country, and, as near as I could estimate, forty feet above the level of the Amazonas at the end of the dry season. This terrace is composed of stratified sands and clays, formed when the strait was bounded by the Santarem and Ereré highlands. The Amazon then formed a tidal estuary that opened to the east into a broad gulf. The Tocantins, the Xingú, the Tapajos, the Maué-assú, the Abacaxis and Canumá, and, very probably, still other rivers to the westward, below their rapids, where they left the Palæozoic basis of the plateau, formed broad estuaries also, with wide mouths. At last, however, the shallowing of the waters of the Amazonas necessitated well defined channels. Islands grew, were fused together and were joined to the mainland, or they narrowed down channels until they formed *paraná mirins.** These side-channels are extremely numerous, and often there are several lying one behind another, and intercommunicating. Though in most cases, I believe, they are due to the growth of islands, rivers frequently flow into them and aid in keeping their channels open.

The growth of the alluvial bottom lands, and of islands, has caused them to encroach on and narrow the mouths of the secondary estuaries, as, for instance, the Xingú and

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*This very expressive Tupí word is derived from *Paraná* (sea or great river), and *mirin* or *miri* (little). It is applied to the river-like and often long side channels that, leaving the main river, flow through the alluvial flood-plain to rejoin it again below. I may take this opportunity to state that the Tupí-speaking Indians call the Amazonas *Paraná*, or, in Portuguese, the sea. This is the answer an Indian will give when asked the name of the Amazonas. The similarity between Maranon, or Maranhao, and Paraná, or paranân (nasal) is very striking; and I am inclined to think that they are the same word. In the Lingoa Geral, or modern Tupí, there are examples of an interchange of M and P; and the Indians who first gave the name to Orellana may have pronounced it with an M, or at least an obscure sound readily mistaken therefor.

Tapajos, or of the Maué-assú. These are clear-water streams, but their current is so slight that, as in the Xingú and Tapajos, the muddy waters of the Amazonas flow in during the dry season and ascend several miles; beside, in flood-time, all the low lands are overflowed and the current of the Amazonas presses the waters of these rivers up against their eastern banks. There is, therefore, a tendency for the Amazonas to build either a point, usually cut through by a *furo* or *paraná-merím*, eastward from the eastern branch of the river, at its mouth, or to form a series of islands. Witness the enormous irregular alluvial deposit that chokes up the mouth of Tapajos Valley on its western side; also, the same feature, with the addition of islands, in the mouth of the Xingú, and how completely the great so-called island of Tupinambarânas has cut off the Maué-assú, Abacaxis and Canumá from the main river, compelling them to empty into a paraná-merím.* The lower Xingú is still an estuary, and for some distance above its mouth is swept by strong tidal currents, which, while preventing the closing of its mouth, have helped build up an immense tract of alluvial land on each side. The so-called river Pará is more properly, to-day, an estuary, freshened by innumerable streams, and by a large contribution from the Amazonas. At Pará the tide runs up with fearful velocity. The amount of water furnished by the side rivers, above named, is very small compared with the immense width of these rivers below their rapids. The mouth of the Tapajos is a little over a mile in width; but inside the river widens rapidly, and soon forms an expanse more than ten miles wide opposite Villa Franca, with a broad water horizon, looking up stream. The same is the case with the Xingú, and on a smaller scale with the three rivers lying between the Tapajos and Madeira. The waters of all these rivers, and here we may also include the Tocautins, are dammed back and spread over the broad valleys, which their clear waters have not yet been able to silt up. The wide lower reaches of these rivers are, then, true lakes, the barrier that prevents their passing into the true riverine condition being the waters of the Amazonas.

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* See Mr. Chandless' excellent paper and maps of these rivers, already cited, also Penna. Regias Occidental da Provincia do Pará.

The flood plain of the Amazonas is diversified by innumerable lakes, some of which, as that of Villa Franca, for instance, are of many miles in length.

In conclusion, I may state that, in the eastern part of the Valley of the Amazonas, I have seen no traces of glacial action, though I have looked carefully for them. While I still adhere to the belief that glaciers once existed on the Brazilian plateau, I see no evidence of their having existed on the Amazonas.

NOTE.—This paper was read just before I made my expedition to the Amazonas in 1871. On my return, I made several important additions and corrections. Owing to my having mislaid a note-book I was unable to give the following heights in the body of the paper and so I append them here:

Serra de Ererê, by barometrical measurement made by myself, 970 feet. There appears to be a point a little higher than the one I selected as the highest, so that the Serra is about 1,000 feet in altitude.

The Serra de Parauâquâra I found to be 1,200 feet high, and the Bluff at Taperinha near Santarem 450 feet.